Weed Technology. 2004. Volume 18:248–251

Individual Plant Control of Tall Larkspur (*Delphinium barbeyi*)with Tebuthiuron[1]

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Abstract: A replicated field trial was conducted to determine the effective rates of tebuthiuron for control of individual tall larkspur plants in the mountains near Emery, UT, Cedar City, UT, and Yampa, CO. The size of larkspur plants was measured, and tebuthiuron was applied to the base of each plant at 0.1, 0.21, and 0.5 g product/1,000 cm^2 of foliar crown cover. Tebuthiuron at 0.21 g/1,000 cm^2 rate controlled 62% of the plants. Tebuthiuron at 0.5 g/1,000 cm controlled 78% of the plants (2.5 g for an average-sized plant of 5,000 cm^2). The high clay content of the soils at Emery or high organic matter content of soils at Cedar City or Yampa did not adversely affect efficacy.
Nomenclature: Tebuthiuron; tall larkspur, *Delphinium barbeyi* Huth #[3] DELBA.
Additional index words: Cattle poisoning, poisonous plant.

INTRODUCTION

More cattle are killed by tall larkspur on mountain summer rangeland in the western United States than any other cause (Pfister et al. 1999). In areas of persistent cattle losses, herbicides have been used to control tall larkspur. Cronin and Nielsen (1972) reported 2,4,5-T and silvex were most effective for tall larkspur control, but these herbicides were subsequently banned. Mickelsen et al. (1990) and Ralphs et al. (1992) recommended picloram, metsulfuron, and glyphosate for specific times of the growing season and site conditions for tall larkspur control. Metsulfuron and glyphosate were effective only when applied early in the season during the vegetative and bud stages, respectively. Picloram was effective throughout the growing season. However, all three herbicides controlled the associated desirable tall forbs, allowing weedy, low-seral forbs to invade and increase after treatment (Ralphs 1995). Furthermore, tall larkspur often grows under aspen trees (*Populus tremuloides* Michx.), thus making broadcast application of these foliar herbicides difficult.

Tebuthiuron is formulated as a 20% pellet and can be selectively applied for individual plant control, it has negligible volatilization and drift, and there are no constraints on time of application. Individual plant treatment would minimize its effect on associated desirable forbs. Tebuthiuron has widespread use in controlling mixed brush species in south Texas (Scifres et al. 1979), oakbrush (*Quercus* spp.) (Scifres et al. 1981), pinyon (*Pinus edulis* Englem.) and juniper (*Juniperus osteosperma* Torr.) (VanPelt and West 1990), and big sagebrush (*Artemisia tridenta* Nutt.) (Baxter 1998). The objective of this study was to determine the effective rates of tebuthiuron pellets for control of individual tall larkspur plants.

MATERIALS AND METHODS

The study was repeated at three locations for 2 yr. The Cedar Mountain site was located 40 km east of Cedar City, UT, at 2,800-m elevation. The habitat type was an aspen–tall forb, with tall larkspur as the dominant forb and western coneflower (*Rudbeckia occidentalis* Nutt.), sweet cicely (*Osmorhiza chilensis* H&A), and meadow rue (*Thalictrum fendleri* Engelm. ex Gray) as subdominants. Mountain brome (*Bromus carinatus* Hooker & Arn.) and slender wheatgrass [*Agropyron trachycaulum* (Link) Malte] were the dominant grasses. The soil was a Fain clay loam (fine, montmorillonitic Argic Pachic Cryoborolls). Detailed soil descriptions at all three sites are presented in Table 1.

The Emery site was located 34 km west of Emery, UT, on the Manti-LaSal National Forest at 3,200-m elevation. The tall larkspur patch occurred in a clearing in the subalpine zone. The habitat type was a tall larkspur–slender wheatgrass–mountain brome and was dominated by these species. The soil was a Greyback clay (clayey-skeletal, montmorillonitic Pachic Cryoboralls).

The Yampa site was located 16 km west of Yampa, CO, on the Routt National Forest. The habitat type was

[1] Received for publication January 20, 2003, and in revised form July 23, 2003.

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

Table 1. Soil characteristics at the three locations.

Location	Depth	Texture	Sand	Silt	Clay	Organic matter
	cm			%		
Emery	0–13	Clay loam	28	40	32	4.5
1998	13–36	Clay loam	22	44	34	2.9
	36+	Clay loam	26	40	34	2.1
1999	0–23	Silty-clay loam	17	46	37	4.5
	23–46	Clay loam	23	46	31	3.9
	46+	Silty-clay loam	15	47	38	3.6
Cedar	0–10	Loam	40	39	21	10.5
	10–56	Loam	31	43	26	4.3
	56–107	Clay	8	36	56	1.6
	107+	Loam	25	50	25	0.8
Yampa	0–22	Loam	38	41	21	11.2
	28–76	Loam	28	45	27	4.3
	76–99	Silty-clay	1	44	55	1.4
	99–117	Clay	16	40	44	1.4

an aspen–tall forb. Tall larkspur was the dominant forb, with cow parsnip (*Heracleum lanatum* Michx.), sweet cicely, and meadow rue as subdominants, and mountain brome was the dominant grass. The soil was a Clayburn loam (fine-loamy, mixed Argic Pachic Cryoboroll).

Tall larkspur is a large robust native perennial forb. Multiple stems grow from its crown each year and average 40 stems/plant (ranging up to 150 stems/plant), which grow to a height of 1 to 2 m. The application rate of tebuthiuron was based on the size of the individual larkspur plants. VanPelt and West (1990) applied tebuthiuron to individual pinyon and juniper trees based on the volume of their foliage. The label recommendation for tebuthiuron treatment of individual plants growing in areas receiving >50 cm precipitation is 0.21 g product/929 cm^2. Tebuthiuron was applied at rates of 0.10, 0.21, and 0.50 g product/1,000 cm^2 of area occupied by the individual treated tall larkspur plants.

The size of each treated plant was estimated by measuring the diameter of each plant at waist height in two cardinal directions and using the average radius to calculate the area of a circle. The amount of tebuthiuron pellets was calculated for the area of each plant and evenly distributed throughout the base of the plant.

Three uniform plants were selected along each of 10 transects (50 m long and 10 m apart). Individual plants were considered experimental units. Transects represented blocks or replications of each treatment. The experimental design was a randomized complete block design with three treatment rates and 10 blocks, repeated at three locations for 2 yr.

The tebuthiuron rate treatments were applied in 1998 and again to new plants in new transects in 1999. They were applied at Cedar City, UT, on July 16, 1998, and July 15, 1999; Yampa, CO, on July 28, 1998, and July 28, 1999; and Emery, UT, on August 14, 1998, and August 5, 1999. Because of elevation differences and different developmental stages, plants at the three locations were not treated at the same calendar dates. They were, however, treated at the same phenological growth stage of early flower, which represents full biomass growth. Treatments were evaluated at the same stage each year.

Data Analysis. Individual larkspur plant mortality was evaluated 2 yr after the 1998 and 1999 treatments. Categorical data (dead or alive) were analyzed using the logistic procedure of PROC GENMOD and the GLIMMIX macro (SAS 1999). These procedures apply logistic regression and general mixed models to categorical data. The model evaluated locations, rates, treatment years, and their two- and three-way interactions. Where differences occurred ($P < 0.05$), means were separated by linear contrasts.

The effect on the environment was estimated by the size of the bare areas left by the treatments. The bare area surrounding the dead larkspur plant was estimated by measuring the diameter from two directions and then using the average radius to calculate the area of a circle. These measurements were taken for 3 yr after the 1998 treatment and for 2 yr after the 1999 treatment. The size of the bare area at the end of the study was the best indicator of the environmental effect of the treatments. Data were analyzed by a mixed model analysis of variance using unstructured covariance (SAS 1999) to compare locations, rates, and treatment years and their interactions. Where differences occurred ($P < 0.05$), means were separated by linear contrasts.

RESULTS AND DISCUSSION

Overall control of tall larkspur increased with increasing tebuthiuron rates ranging from 50% for the 0.1 g/1,000 cm rate to 78% for the 0.5 g/1,000 cm rate (Table 2). There were no significant interactions between rate and the other factors. There was a location by year interaction ($P = 0.0001$), indicating tebuthiuron was not uniformly effective in all locations in the two application years. Tall larkspur control was lower at Emery in the 1998 treatment year than at Cedar or Yampa, but control was lower in the 1999 treatment year at Cedar and Yampa. The high rate of tebuthiuron at Cedar in 1999 provided only 40% control, which was lower than the middle rate and much lower than the high rate in other years and other locations. One or two stalks survived on these plants, and they had returned to a normal growth pattern when evaluated 2 or 3 yr after treatment. A more uni-

Table 2. Control of larkspur plants treated with tebuthiuron at three rates.

Location	Treatment year	Rate[a] 0.1 g	0.21 g	0.5 g	Mean
		% mortality			
Emery	1998	30	30	60	40
	1999	80	80	100	87
	Mean	55	55	80	
Cedar	1998	70	90	100	87
	1999	30	70	40	47
	Mean	50	80	70	
Yampa	1998	70	70	90	77
	1999	20	30	80	43
	Mean	45	50	85	
Grand rate[b]	Mean	50 b	62 b	78 a	

[a] Treatments are grams per 1,000 cm^2 of plant area.

[b] Grand rate means over locations and years followed by the same letter are not significantly different as determined by linear contrasts ($P < 0.05$).

form application of tebuthiuron pellets throughout the crown would have prevented survival of the outer stalks.

The size of the bare areas where tall larkspur plants died increased with increasing rates of tebuthiuron (Table 3). There also was a location by year interaction ($P = 0.0006$). The bare area at Emery in 1999 was more than double that at any other location or year. The Emery site received 13 cm of rain in August 1999 after application of tebuthiuron, compared with 4.3 cm of rain in August 1998 and 2 to 7 cm at Cedar or Yampa in both years. The authors speculate that additional precipitation spread the herbicide over a larger area.

The average size of bare areas of soil after the 1998 tebuthiuron treatments were only half the size of the original plants at Emery. Bare areas in 1999 were close to the original size of tall larkspur plants. Bare areas at the other two locations were only 20 to 30% of the original size of larkspur plants. The bare spots should quickly fill in with the adjacent plants, such as mountain brome, slender wheatgrass, and meadow rue (Ralphs 1995).

The high clay content of soils at Emery or the high organic matter content at Cedar or Yampa (Table 1) did not seem to adversely affect tebuthiuron efficacy. It has been reported that the efficacy of tebuthiuron is reduced on soils high in clay or organic matter (Duncan and Scifres 1983). They reported that as the clay content of soil increased, efficacy of tebuthiuron decreased, and they suggested that phytotoxicity was greatly diminished in soils having more than 30% clay. Clay content at Emery exceeded 30%, yet control was not diminished. Concentrating tebuthiuron at the crown of tall larkspur apparently provided sufficient herbicide to kill that plant.

Tebuthiuron at 0.21 g/1,000 cm^2 killed greater than 70% of tall larkspur plants at Cedar but provided variable control at Emery and Yampa. Tebuthiuron at 0.5 g/1,000 cm^2 (2.5 g for an average-sized plant) killed 78% of the plants. If the tebuthiuron pellets were uniformly applied throughout the entire base of the tall larkspur plants, all the plants should have been controlled (personal observation). In a preliminary study near the Cedar site, tebuthiuron applied at 3 g/plant killed all treated larkspur plants after 2 yr (L. Woolsey, unpublished data) There was no sign of damage on associated vegetation. The bare areas that remain will be filled in by the adjacent vegetation.

There is some question about the practicality of treating individual plants. VanPelt and West (1990) applied tebuthiuron to individual juniper and pinyon trees that were left after chaining operations. Tree density was 248 trees/ha, and they estimated that they were able to treat about 1 ha/h and missed only 10% of the trees. In central Utah, tall larkspur grows in patches in snowdrift sites

Table 3. Initial plant size and size of bare areas (±SE) after tebuthiuron application at three rates.

Location	Treatment year	Initial plant size	Bare area after treatment: Rate[a] 0.1 g	0.21 g	0.5 g	Mean
		cm^2				
Emery	1998	3,652 ± 384	1,863 ± 378	1,450 ± 290	2,023 ± 293	1,792
	1999	4,936 ± 436	3,310 ± 496	3,676 ± 529	4,943 ± 855	4,051
	Mean		2,915	2,722	2,645	
Cedar	1998	5,681 ± 512	717 ± 267	1,053 ± 237	1,291 ± 240	1,054
	1999	3,814 ± 300	880 ± 241	989 ± 51	751 ± 146	900
	Mean		766	1,023	1,139	
Yampa	1998	5,405 ± 642	1,061 ± 410	1,735 ± 506	1,924 ± 421	1,609
	1999	5,445 ± 570	374 ± 220	1,342 ± 387	2,651 ± 617	1,998
	Mean		889	1,604	2,285	
Grand rate[b]	Mean		1,615 b	1,786 b	2,461 a	

[a] Treatments are grams per 1,000 cm^2 of plant area.

[b] Grand rate means over locations and years followed by the same letter are not significantly different as determined by linear contrasts ($P < 0.05$).

(0.5 to 4 ha in size with a density of 1.3 plants/m^2). These patches could be easily treated by hand. Trampling each plant by placing a foot in the crown and smashing the stems would make it easier to distribute the tebuthiuron pellets, as well as to mark the plants that were treated. The cost of tebuthiuron at the high rate was about 5¢ US per plant. Ralphs et al. (2003) reported the costs to control tall larkspur with spot treatments of ammonium fertilizers and salt on individual plants were 12.9¢ US and 2.6¢ US, respectively.

LITERATURE CITED

Baxter, G. 1998. Thinning dense sagebrush stands with Spike 20P. Rangelands 20:14–16.

Cronin, E. H. and D. B. Nielsen. 1972. Controlling tall larkspur on snowdrift areas in the subalpine zone. J. Range Manage. 25:213–216.

Duncan, K. W. and C. J. Scifres. 1983. Influence of clay and organic matter of rangeland soils on tebuthiuron effectiveness. J. Range Manage. 36: 295–297.

Mickelsen, L. V., M. H. Ralphs, D. L. Turner, J. O. Evans, and S. A. Dewey. 1990. Herbicidal control of duncecap larkspur (*Delphinium occidentale*). Weed Sci. 38:153–157.

Pfister, J. A., D. R. Gardner, K. E. Panter, G. D. Manners, M. H. Ralphs, B. L. Stegelmeier, and T. K. Schoch. 1999. Larkspur (*Delphinium* spp.) poisoning in livestock. J. Nat. Toxins 8:81–94.

Ralphs, M. H. 1995. Long term change in vegetation following herbicide control of larkspur. J. Range Manage. 48:459–464.

Ralphs, M. H., J. O. Evans, and S. A. Dewey. 1992. Timing of herbicide applications for control of larkspurs (*Delphinium* spp.). Weed Sci. 40: 264–269.

Ralphs, M. H., L. Woolsey, and J. E. Bowns. 2003. Mechanism by which ammonium fertilizers kill larkspur. J. Range Manage. 56:524–528.

[SAS] Statistical Analysis Systems. 1999. SAS/STAT User's Guide. Version 8e. Cary, NC: SAS Institute. 3884 p.

Scifres, C. J., J. L. Mutz, and W. T. Hamilton. 1979. Control of mixed brush with tebuthiuron. J. Range Manage. 32:155–158.

Scifres, C. J., J. W. Stuth, and R. W. Bovey. 1981. Control of oaks (*Quercus* spp.) and associated woody species on rangeland with tebuthiuron. Weed Sci. 29:170–174.

VanPelt, N. S. and N. E. West. 1990. Effects of manual application method on application time, thoroughness and tebuthiuron outlays. J. Range Manage. 43:39–42.